DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS

Research and Development

Final Project Report

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CSG 15

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DEFRA project code	**MF0735**
Contractor organisation and location	Sea Mammal Research Unit Gatty Marine Laboratory University of St Andrews St Andrews, Fife KY16 8LB
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Project start date	25/11/02
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Executive summary (maximum 2 sides A4)

This project continued the work begun in 2002 investigating dolphin bycatch in the pelagic pair trawl fishery for bass and designing a means of minimising this bycatch.

The prototype grid system developed under MF0733 in 2002 was returned to the Institute of Marine Research in Bergen in November 2002, where some alterations and adjustments were made to the net section in which the grid was placed, to the angle of the grid, and to the cover net that covers the escape hole. We also adjusted the number and orientation of the floats set around the grid. A Fuller description of the grid was presented in the report on MF0733 in 2002. We were loaned a Scanmar Grid Sensor by the IMR which monitors the angle of the grid and water flow rate, and transmits these readings back to one of the vessels every 13 seconds using an acoustic signal.

A twin camera system was designed and implemented by Prove Systems (Tayport, Fife) to enable us to monitor both grid and escape hole from the interior of the net and the escape hole and cover net from the outside. Video images were carried from the cameras by cable to a winch on deck, and from there to the wheelhouse for continuous display and recording onto SVHS tape. Initially we used two Simrad SIT cameras on hire and an L.E.D. lighting system designed by Prove systems.

We chartered a suitable team of pelagic pair trawlers for work in December 2002, on the assumption that dolphin bycatch would be less likely then than during the peak of the season in March. This was considered important because we wanted to ensure that fish loss could be minimised, and that any necessary alterations to address this issue, and measurements of fish loss were complete before trying the system out in the period of peak dolphin bycatch.

We were forced to modify the initial plan because one of the chartered vessels was involved in a collision and needed to go into dry dock for repairs. We therefore ran the trial in the peak season of March.

We deployed the grid and camera system on the chartered pair working out of Plymouth on March 14th. Fortunately the grid system worked extremely well with respect to the fish. Some initial fish loss was eliminated by altering the escape hole cover net and video monitoring demonstrated negligible loss of fish thereafter. For confirmation of this we also used a collection bag over the escape hole on just two tows as we were aware that other vessels around us were taking dolphins in their nets and did not wish to risk inadvertently drowning dolphins in the collection bag. During these two tows just one bass was recovered from the collection bag, a loss rate of well under 1%, which the skippers were very happy with.

The grid system has proven relatively straightforward to work, though there is an overhead in crew time shooting and hauling the grid that has to be winched over the stern rail.

Over the charter period we monitored 31 tows, but we did no observe any dolphins in front of the grid, nor any escaping through the escape hole. The skippers volunteered to continue monitoring the system after the charter period had ended. A further 51 tows were monitored, though with a single internal camera system, until the end of the fishery on May 8th. For three nights after the Charter period (28th-30th March) the picture quality of the remaining single camera was too poor to obtain a clear image. The reason for this was not clear, but may have been due to a voltage supply problem or the orientation of the lighting. The problem was resolved on 31st when a new prototype CCD camera was supplied by Prove systems and installed to replace the SIT camera.

On the night of 28th March two common dolphins were recovered from the trawl after it had been hauled. One of these had become caught by its beak in the cover net, and had apparently blocked the escape hole for the second animal. Both had drowned. We conclude from this that the cover net mesh size is too large and needs to be substantially reduced to eliminate this possibility in future.

We also made observations on other Scottish pair trawlers working in this fishery in the same area in March. These suggest that dolphin bycatch rates were relatively high in the 2003 season in this fishery. The other two pairs working the area during the charter period reported frequent bycatches and one of the skippers kept a record for us for part of that time. Based on these observations, the expectation would have been that one in every five tows should have caught one or more dolphins. Our observation of zero catches in 31 hauls during the charter period is therefore very unlikely ($p<0.001$), and we conclude that the system was effective in deterring animals from the dangerous part of the net, the tunnel leading to the cod end. The deaths of just two animals during all 82 monitored tows, while clearly not as good as a zero mortality rate, represents an order of magnitude improvement in the bycatch rate in the first full scale mitigation trial in this fishery.

While it is clear that the system is effective in reducing dolphin bycatch, the exact mechanism is unclear. As we did not observe any animals during the charter period entering the grid section of the net, we conclude that they were probably deterred from trying the swim down the tunnel towards the cod end, and most likely swam out of the net the way that they had entered. We suggest that either they were able to detect the net inside the tunnel leading to the cod end and correctly interpreted it as a barrier to progress and turned around before entering the narrow tunnel leading to the cod end, or they were deterred from the tunnel by the Scanmar grid sensor. This device emits a loud signal at regular intervals and at frequencies used by dolphins to echolocate.

We intend to introduce similar systems to the other UK pairs working in this fishery in the coming season (winter 2003/2004) and will monitor how they perform, while trying to determine whether the grid itself or the grid sensor are most important in deterring dolphins from the tunnel region of the nets. We will also improve the escape hole cover net to try to ensure that dolphins cannot get their beaks caught as they escape on the rare occasions that they do enter the tunnel section.

We are also actively engaged in dialogue with French colleagues and industry to establish collaborative studies with the French bass pair trawl fleet next season. A short explanatory video is also being prepared and will be submitted to DEFRA in due course.

Project title	Further development of a dolphin exclusion device	DEFRA project code	MF0735

Scientific report (maximum 20 sides A4)

INTRODUCTION

Background

Over the past several years there has been considerable concern surrounding the numbers of dead dolphins stranded on beaches of Devon and Cornwall in the winter months. Common dolphins make up the greatest number of stranded animals, with annual totals for most years of between 30 and 50 common dolphins. Veterinary investigations have made it clear that a substantial proportion of these animals have died as a result of entanglement in fishing gear. In the winter of 1991-1992 and again in the winter of 2002-2003 the numbers of animals stranded increased considerably to well over a hundred (132 in the first quarter of 2003).

Although it is known that the cause of death of a substantial proportion of these animals is due to physical trauma as a result of entanglement, it is not possible to determine which specific fisheries are implicated in any particular case. Previous on-board observer programmes have suggested annual takes of around 200 dolphins per year in the hake gill net fishery (Tregenza and Collet 1998), and dolphin bycatches have also been observed in horse-mackerel fisheries operating in the Celtic Sea and Channel, in tuna pair trawls and driftnets operating in the Biscay region (though in the summer only), in French hake pair trawls and in French bass pair trawls (Morizur, Tregenza et al. 1996). It is therefore known that common dolphins are subject to mortality in at least two broad types of fishery, namely static nets and pelagic trawls. Most public and scientific interest has been centred on the pelagic trawls.

There are several pelagic trawl fisheries operating in this region during the first quarter of the year, including French, Irish, Danish, Dutch and UK vessels variously targeting herring, mackerel, horse-mackerel, sardines, sprats, bass and more sporadically anchovy and sea bream.

Mitigation trials with the UK bass fishery

In 2000 SMRU was contacted by the Scottish Fishermen's Federation and the Scottish Pelagic Fishermen's Association to help address a problem of dolphin bycatch reported by the skippers involved in the UK bass pelagic pair trawl fishery in the Channel. Since that time we have been working closely with skippers from this one small fishery to attempt to minimise or eliminate dolphin mortalities in that fishery.

The winter bass fishery in the UK has several components, including gill-netters and inshore trawlers that target bass in coastal waters (inside 6 miles). Further offshore several pairs of Scottish boats (4 pairs in 2002-2003) fish for bass mainly in late February and March as bass move offshore to spawn. It is these vessels that we have been working with. Further information on seasonality and trends in fishing effort has been presented separately (Northridge 2003).

Our attempts to mitigate dolphin bycatch with the skippers of this fishery have been focussed around the use of acoustic deterrent or warning devices and the use of exclusion grids. In 2001 and again in 2003 we used commercially available pingers to see if we could detect any possible effect on bycatch. These tests are described in more detail elsewhere (Northridge 2003). Although we cannot rule out the use of pingers as a mitigation measure, as present other methods seem more promising.

Preliminary observations in early 2001 had indicated relatively high dolphin bycatch rates in the UK bass pair trawl fishery with 53 animals observed taken in 116 tows. Tows last on average around 7 hours, and dolphins were usually taken in small groups (range 1 to 10 average 4.4). Of the 116 tows observed in 2001, 12 (10%) had one or more dolphins as bycatch.

Preliminary grid trials of 2002

In 2002 we ran a preliminary trial of an exclusion grid on board one of the commercial pairs of trawlers fishing for bass in the western Channel. The results of this study were presented in our report on contract MF0733. A schematic diagramme is shown in Figure 1. The grid was designed by Norwegian fishing gear technologist Bjoernar Isaksen and built to his plans by SeaFish in Hull. We used a Simrad SIT camera with a 600m cable relaying a real-time view of the grid and associated escape hatch to the bridge of the ship. We had planned to make two trips of some 8 days in total with an anticipated 16-20 tows, in the expectation of seeing at least one tow with dolphins.

The main objectives however were to determine if the grid would work in a real fishery and how the bass would react to it. Due to a cable breakage we only managed to monitor 9 hauls and no dolphins were seen inside the trawl, but we achieved all of our other objectives. We were able to determine that the grid system could be handled relatively easily on board, and that it did not adversely affect fishing. Furthermore, the bass did not appear to be unduly affected by the presence of the grid. Nevertheless we did experience some bass loss through the escape hole, which we were not able to quantify. This preliminary exercise was done at the skippers' risk and not as a charter project.

Objectives of the 2003 trial

In the present project we aimed to develop the system further. Our primary objective was to make changes to the grid design so that we could eliminate any loss of bass during fishing.

To do this we aimed to charter two Scottish pelagic trawlers working as a pair team for 12 days. We also aimed to make some necessary adjustments to the 2001 grid system to eliminate fish loss, and to develop and implement a dual-camera monitoring system to monitor the grid and the escape hole. Another aim was to quantify fish loss through the escape hole. Our initial aim was to run the charter just before Christmas, a time when bass catches are not at their highest, but also a time when previous observations suggested that we would be less likely to encounter dolphins. This was because we wished to ensure the system worked with respect to bass before testing it in the peak dolphin bycatch season of March.

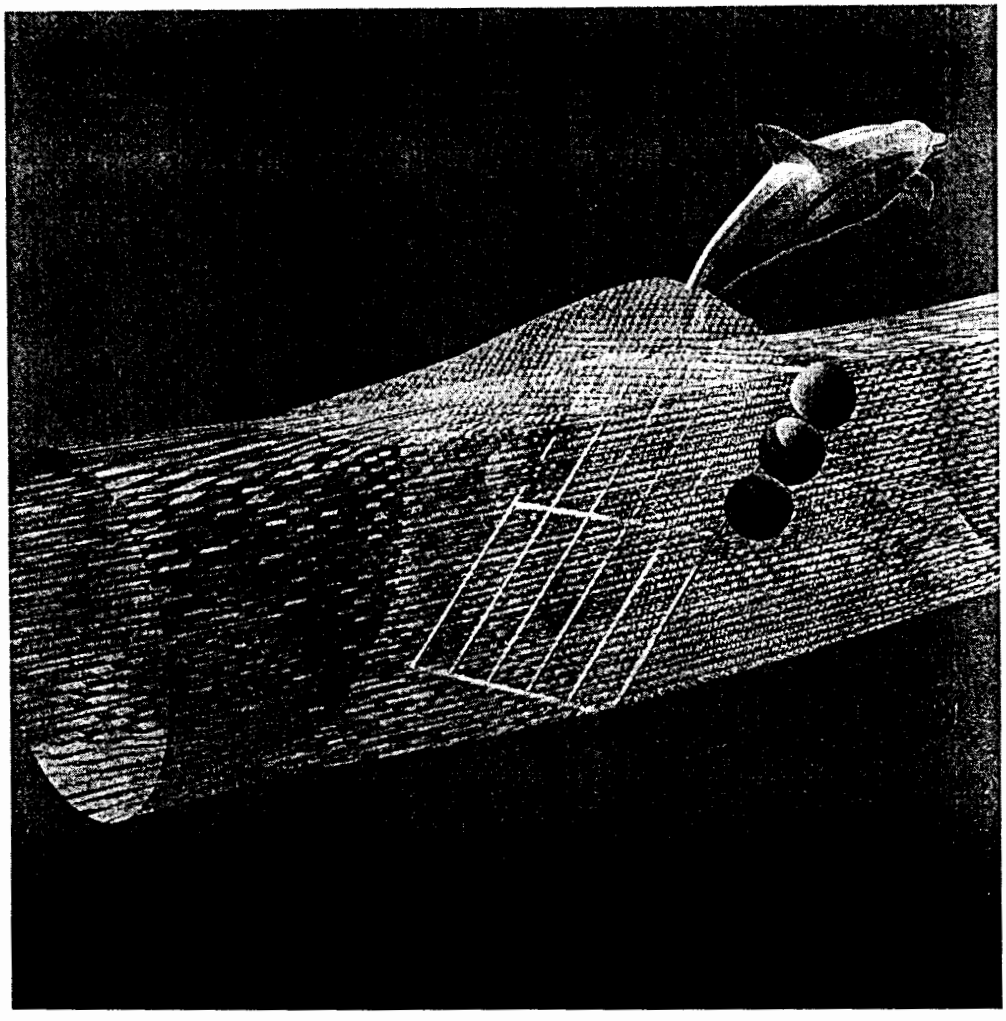
Due to a collision between one of the charter boats and the Dutch research vessel Tridens a few days before the scheduled charter we had to postpone the charter period until the main fishing season. We therefore ended up having to test the equipment's ability to catch bass at the same time as testing its ability to allow dolphins to escape.

The reason for developing a twin camera system was that the prototype trial in 2002 had been criticised as being unable to determine whether or not any escaping animals would do so unharmed by the grid. We therefore anticipated using an additional camera fixed to the outside of the net with a clear view of any animals as they escape, on the assumption that their swimming behaviour would indicate whether they had been harmed in any significant way.

In part because of this criticism we also arranged to borrow a Scanmar grid sensor from IMR in Norway that would measure both the angle of the grid in the water, and more importantly the water flow over the grid, or the real speed of the grid through the water. Clearly this would affect the force of contact with any animal that might collide with the grid.

To quantify fish losses we used a collection bag that can easily be sewn onto the outside of the grid extension piece to cover the escape hole and collect any escaping fish. Clearly this is a risky thing to do when there are dolphins around as it would also mean that any dolphin escaping through the escape hole would drown in the collection bag. Moving the trial from December to March increased this risk, but this method was considered the only reliable means of quantifying fish loss.

Figure 1: Schematic representation of the dolphin exclusion device. Grid and dolphin approximately to scale. (Dolphin ~2m in length)



METHODS USED

We consulted with Bjoernar Isaksen about the performance of the grid during 2002, and he reviewed several hours of video tape from inside the trawl. He concluded that several adjustments to the design needed to be made. The grid was therefore sent to Norway to be re-rigged in a new piece of netting, using a different mesh size and type and set at a slightly steeper angle. A new cover net for the escape hatch was also implemented. Furthermore he advised changes in the deployment of floats around the grid. All of these changes were made and the grid was shipped to the UK in early March 2003 inside its own section of trawl netting that can be slotted into the extension piece of the existing trawl.

To address the issue of a twin camera monitoring system we contracted Prove Sytems (Philippe Hubert) in Tayport, a company with many years of specialist work in subsea monitoring with the oil industry, to help design and develop a suitable camera and lighting system. To this end we hired a 900m Rochester armoured cable with twin coaxial and power supply lines. We also hired two Kongsberg Simrad OE1324 SFT Low Light cameras. Prove systems supplied their own high-powered LED light sources. We used two SVHS Sony Video tape decks and two monitors in the wheelhouse to monitor and record the tow views of the net onto 4 hour SVHS tapes. Much of the time, we also diverted the signal from the interior net camera to a 17" flat-screen monitor in the wheelhouse to make visual monitoring easier (Figure 2).

Figure 2: The wheelhouse: continuous monitoring of the grid was possible using a large flatscreen display

We chartered the same two Scottish vessels with whom we had worked in the previous year. They joined the bass fishery on March 10th and made one trip, reporting no dolphin bycatches between 11th and 13th. Project personnel joined the pair in Plymouth on 13th March. These included Martin Cawthorn of Cawthorn Associates in New Zealand, who has worked for several years with Australian and New Zealand fishing companies refining Isaksen's original sea lion escape device (SLED) for hoki and squid trawls ((Gibson and Isaksen 1998)). He was present on board from 14th to 24th March. Philippe Hubert of Prove Systems accompanied the pair from 14th to the 17th March on the first trip to set up the video equipment and to ensure it was working properly. Dave Sanderson from SMRU was with the vessel as main observer throughout the trials, and Simon Northridge was also present from 17th until 24th March.

The vessel's crew fitted the grid in its netting section into the front end of the trawl tunnel. Two cover nets were available, one white and one black, both constructed from 40mm nylon mesh. The black net had in addition been subjected to a stiffening agent while the white cover net had not and was therefore more flexible.

A collection bag was constructed by Bjoernar Isaksen to fit over the escape hole, and this was fitted with 4 eight-inch floats to keep it open.

The cameras and lights fitted inside two specially constructed stainless steel cages about 50cm long and 20cm deep. These cages were lashed one to the inside and one to the outside of the trawl. The Rochester cable was terminated with a 'spider' of several kevlar cables connecting lights and cameras to the main cable. At the other end the Rochester cable was wound onto a self-tensioning deck winch with four slip-rings to connect via a deck cable to the power supply and the video monitoring unit in the wheelhouse.

EXPERIMENTAL NARRATIVE

A full day was spent rigging the grid and camera systems on the vessel in Plymouth. During the first trip of the charter period (15-17th March) 7 hauls were made with no dolphin bycatch. A number of minor problems were identified with both the grid system and the video system, and these were rectified. During the first haul the grid inverted and additional floats were placed on it to prevent this from recurring. One of the camera cables also parted and had to be repaired on board. There is considerable elasticity in the nylon cod end and tunnel section of the trawl, which can lead to cables being over-stretched, and this is an issue that needs to be considered whenever cables are being used.

By the end of this first trip the camera system and the grid system were both working satisfactorily. Nevertheless, throughout the trials there were continual minor problems with voltage fluctuations to the camera that necessitated adjusting the voltage of the power

supply. It was not clear if these problems were due to the rather old armoured cable, to some possible wiring problem or possibly to faults at the slip-rings (build up of dirt).

During the second trip (17-19th March) fishing continued in the same general area southeast of Plymouth. Six tows were conducted and no dolphins were seen. During one tow the cover net fell inside the escape hole during shooting, and became entangled in the bracket holding the Scanmar grid sensor that was bolted to the rear side of the grid. This meant that there was a large escape hole easily visible to the fish, and fish began to escape through this. The net was hauled and re-shot without further incident. In a subsequent tow one side of the trailing edge of the cover net also fell inside the escape hole allowing an estimated 26 fish to escape. This problem was rectified by attaching a length of lightweight leadline to the trailing edge of the cover net, which prevented any subsequent problem of this nature. After this fault had been rectified we attached the collection bag over the escape hole for two tows and collected just 1 fish that had escaped through the escape hole. This was in any event an under-sized fish measuring 36cm. During these two tows 11 baskets, numbering an estimated total of 480 fish, were taken, suggesting a loss rate of less than 0.5%. Although we did not see any dolphins, were heard from the two other Scottish boats fishing within a few miles of us, that both had taken several dolphins overt his period.

The third trip (19th-20th March) consisted of just two hauls after a minor fault (loss of power) developed with the lights and camera and we returned to Plymouth for a few hours while a local electrician carried out repairs.

The fourth trip was conducted between 20th and 24th March during which 10 hauls were made. Again no dolphins were seen inside the net. During this period we also changed the cover net, removing the black net and replacing it with the white one. The white net had not been stiffened and our impression was that it hung more loosely, with folds hanging slightly into the escape hole. Nevertheless we also thought that the behaviour of the fish may have changed: Whereas bass had previously congregated under the black escape hatch cover just in front of the grid, this seemed to occur less frequently with the white cover, and more often they swam back toward the cod end. For this reason we kept the white cover net in place for the rest of the trial. At the end of this trip the Scanmar grid sensor was removed in preparation for its return to Norway.

The final day of the charter period was the 25th, but the vessels stayed out until the 28th continuing the work. A further 6 tows were made during this trip.

Overall during the charter period, including 25-28th March, 31 tows were made.

After March 28th, the skippers volunteered to keep one of the cameras on board, to continue to use the grid and to continue to monitor and record the video image from inside the trawl. They continued fishing until May 8th for most of which time Dave Sanderson (SMRU) accompanied the vessels and monitored the grid performance. During his few days absence, the crew continued to record the video signal for all tows.

After the charter period, on March the 28th, to minimise costs, one of the cameras was taken off the vessel and one of the lights removed. Unfortunately it was not realised until the night of 28th that this re-arrangement had upset some aspect of the lighting-camera system, and much of the night-time picture was obscured through interference with lights or inadequate voltage supply. This was rectified on 31st March when a replacement camera was supplied on loan from Prove systems which proved much more robust to voltage and lighting problems. During this period of three nights we were therefore without a view of the grid (though during daytime there was no problem). On the night of March 29th two common dolphins were recovered from the trawl upon hauling. One of these animals had become caught by its beak in the small meshes of the escape hole cover net, apparently blocking the exit for the second animal.

Between March 28th and May 8th we monitored a further 36 hauls, while the skipper and crew monitored and recorded an additional 15 tows. In total therefore 51 additional tows were monitored after the 31 tows made during the charter period, with a total of 82 tows over the entire fishing season of 8 weeks, with two dolphin mortalities.

RESULTS

The grid system performed substantially better than in the preliminary trial in 2002. It was clear from the video images that the grid was better placed in the net causing less distortion. It was also clear from the video images that once we had fixed a couple of minor problems with the cover net, fish escape was almost zero. Indeed we did not subsequently observe any fish escaping (the top mounted camera provided a good view of this). The collection bag experiment that we conducted confirmed that fish loss is negligible, at 1 (undersized) fish escaping among approximately 480 caught. We did not undertake more than 2 tows with the collection bag in place, due to concerns that we might inadvertently trap a dolphin.

Measurements from the grid sensor indicated that the water flow rate over the grid is somewhat slower than the speed of the boats through the water. This was the expected result, as in general when a net is towed through the water the effects of drag mean that

some of the water is effectively pulled forward with the net. The speed of the grid through the water was typically in the range of 1.8-2.4 knots, compared with typical towing speeds (over the ground) of around 3.5 knots.

The grid angle was measured at around 44° at the start of the trial, but after two weeks this had reduced to around 39°. The probable reason for this is that the nylon netting material may have stretched slightly, thereby altering the angle of the grid, though there was no noticeable effect on the behaviour of the fish.

The camera system worked well, despite a few technical problems. We found that the SIT cameras that we hired were somewhat difficult to supply the correct voltage and light levels to enable a good quality image to be returned. The replacement camera supplied by Prove systems, which is a prototype low light level CCD camera that they are developing, proved much more stable and reliable with no apparent loss of picture quality.

The grid as currently designed appears to work well from a fishing point of view with no apparent impact on fish catches. There is a small overhead for the crew in shooting and hauling the net with a grid in place. Whereas the net itself can be shot and hauled over the stern rail, the grid needs to be lifted over the stern rail every time it is shot or hauled. As it weighs around 70Kg, this is not a completely trivial task. However, by using the power block (winch) that is used to lift the bag end onto the deck, the grid can be hoisted over the stern rail in either direction in under a minute. Clearly a flexible grid that could be shot and hauled over the stern rail would be preferable. This is something we intend to pursue.

The entanglement of two dolphins was a matter of great concern, and it appears that the escape hole cover net was not constructed with small-enough meshes. We used a 40mm (stretched mesh) net, whereas in the Eastern Tropical Pacific tuna fishery a 32mm (stretched mesh) size net is used in the Medina panels of netting that are used to guide dolphins out of purse seine nets. The 32mm mesh size was chosen so as to ensure dolphins cannot get their beaks caught in it. In future we will use an even smaller mesh size.

The fact that we did not observe any dolphins inside the trawl during the charter period was surprising. Observations made during previous years indicate that 1 in 4 hauls in March 2001 and 1 in 20 in March 2002 had caught 1 or more dolphins, so we might reasonably have expected at least 1 such incident, and possibly as many as 7 or 8 such incidents in the 31 tows made during the charter period, depending on prevailing conditions in 2003.

During both February and March 2003 on-board observations on two of the other three pairs working this fishery revealed that dolphin bycatch rates were high in 2003, with 6 out of 32 hauls catching 1 or more dolphins (see Table 1). Furthermore during the charter period we heard from vessels fishing nearby that animals were being taken. If we include records that one of the other skippers supplied to us for the same period, 9 out 45 hauls (0.20) in this fishery during February and March had one or more dolphins present. If we therefore assume the same catch rate of dolphins should have applied to the charter vessels as to the rest of the fleet, fishing in the same area and at the same time, then we would have expected 6 of the 31 hauls during the charter period to have had dolphins. On this assumption, a binomial goodness-of-fit test indicates that the probability of observing no such events is 0.00099 or less than 1 in a thousand. It is therefore highly unlikely that our observations of no hauls with dolphins could be due to chance. Even if all of March is considered, with 1 dolphin-tow among 41, the probability of this occurring if both types of vessels were equally likely to catch dolphins would be 0.0012, or just over 1 in a thousand.

Overall, although two dolphins were caught and died during the eight weeks of overall observation, this catch rates is very much lower than we would have expected. Referring again to our observations during February and March, where 28 individuals were recorded in 32 tows, we might have expected a total mortality of around 70 animals in these 82 tows. In reality this comparison is probably unfair, as bycatch rates are highest in late February and March and fall off considerably thereafter, when half the tows were made by the trial pair team.

If we therefore consider only the 41 tows made during March, both during and after the charter period, we would have expected to take around 35 dolphins, compared with the two that were actually caught. This is equivalent to a 94% decrease in bycatch rate.

Table 1. Summary of observations and dolphin bycatch records from the UK bass pair trawl fleet in 2003

Observation type	No of tows recorded	No of tows with dolphins ('dolphin-tows')	No of dolphins	Dolphin-tow rate
Non-Grid Boats				
February	16	3	16	0.187
March: *SMRU observed*	16	3	12	0.187
March: *Skipper reported*	13	3	9	0.231
All March	29	6	21	0.207
April	17	0	0	0

Grid Boats				
March -charter	31	0	0	0
ALL March	41	1	2	0.024
April	41	0	0	0

DISCUSSION

Our primary objective was to test a redesigned grid system to ensure that it would work profitably in the bass fishery. Initially we had intended to do this in December and then use a proven system in the fishery in March to test its effectiveness in reducing dolphin bycatch. In the end we had to test both functions at the same time. We believe that we have clearly demonstrated that the system can be used in the bass pair trawl fishery, though clearly further refinements would be welcome. These include use of a different material for the grid, and a different net type for the cover net.

The system appears to be very effective in reducing dolphin bycatch, but we are not yet sure why. There are several possibilities. The first is that the grid itself, being solid stainless steel, can be detected by dolphins and that they therefore avoid it. The tunnel into which the grid is fitted is about 40m long, ending in the cod end. It is around 1.8m in diameter and would be difficult if not impossible for an animal of 2m or more to turn around once it had begun to swim down such a tunnel. Further forward however, like a funnel, the net gets wider, having a diameter of around 5m at a distance of around 10m from the tunnel entrance. Thus an animal approaching the tunnel, assuming it is daylight or that the animal is echolocating, should easily be able to detect the grid, and may correctly interpret it as a barrier to progress, and so turn around at that point, before entering the confines of the tunnel, and therefore before coming into the field of view of the camera.

The swimming distances involved for a dolphin to escape through the front of the net are not significant. From the grid to the headline is a distance of around 130m, and around 200m to the leading edge of the wings. For an animal that swims easily between 2 and 4m per second, and is capable of burst speeds of much more than this, swimming from the entrance to the tunnel to the headline would take at most 65 seconds.

A second possible explanation is that some aspect of the experimental gear warned the animals away from the tunnel. The most likely thing here would be the Scanmar grid sensor (Figure 3). The grid sensor emits an acoustic signal carrying information about the grid angle and water speed back to the ship. The signal has a source level of 186dB re 1μPa @1m, and a frequency spectrum of 40-43Khz.

Figure 3
Scanmar Grid Sensor Unit
25 x 24 x 9 cm

These acoustic characteristics mean that this is a relatively loud acoustic signal that lies in the centre of the frequency range used by common dolphins (and many other small cetacean) to echolocate. In the case of common dolphins echolocation clicks are thought to be in the 23-67Khz range (Dziedzic 1978).

The fact that the grid sensor was removed from the grid just a few days before the two animals were recovered from the net lends weight to this hypothesis. The question therefore remains whether the grid system alone will also work to exclude dolphins in either the intended or other manner without the gird sensor. This remains unclear at present, but on the night of the 30th (the night after the two animals were recovered from the net) the very poor pictures recorded suggest that there may have been one or more animals present in front of the grid at one point in time. No dolphins were present when the net was hauled. This suggests that the grid alone did also serve some function in deterring or excluding animals from the net.

It is also worth noting that most of the vessels in this fleet use Scanmar net sensors to monitor the amount of stretching in the cod end as an indication of fish catch. These devices use much the same frequency spectrum as the grid sensors, but evidently fail to keep animals out of the cod-end. However, the fact that the grid sensor was placed so far forward, close to the entrance to the tunnel, may help to explain this.

The possibility that some other aspect or aspects of the experimental gear such as the lighting or the cables may have warned the animals away cannot be ruled out, but seems less likely. The lights are directional and pointed backwards towards the grid, and were not visible during daylight, yet we know that bycatches of common dolphins occur in this fishery during daylight. The cables run outside the net and would be less detectable than other aspects of the system such as the grid or the grid sensor.

The readings that we obtained from the Scanmar grid sensor, which we recorded several times during each tow of the charter period, indicate that water flow rates over the grid were quite slow, generally around 2.2 knots, but ranging from less than 1 knot to 2.8, depending on the tide. It seems very unlikely that at such a slow speed the grid would represent any serious threat to any marine life coming in its way, especially something as robust as a dolphin.

It is also very unlikely that such an animal would propel itself onto the grid at any significant speed given the confined nature of the tunnel in which the grid is placed, and the animals' excellent visual and acoustic detection abilities. The proposition that the grid might threaten the animals that it is intended to steer out of harm's way appears to have resulted from a mis-interpetation of an unpublished draft veterinary report on sea lions that were taken in squid and hoki trawl fisheries in New Zealand.

CONCLUSIONS

At present, although we can be confident that full the system as used was effective in minimising dolphin mortality we cannot be sure why this was the case. The most likely explanation is that the grid itself or the grid sensor, or both, acted as a warning to dolphins and prevented them, most of the time, from entering the cod end tunnel. (This is the area from which all the dolphins that we have observed drowned have been recovered). On one or possibly two occasions this deterrent effect did not work, and two animals drowned as a result. Their drowning seems to be because the mesh size that we used in the escape hole cover net was slightly too large, allowing one of their beaks to become caught.

All the skippers likely to be operating in this fishery next season have indicated that they will be willing and eager to use parts or all of the system described here to minimise dolphin bycatch.

We intend to work with them to introduce the elements of this system into all the vessels next season. We will also try to ascertain which elements of the system are indispensable, whilst minimising the risks to the dolphins concerned. Clearly if the grid alone or the acoustic device alone can do the job, then the other device becomes redundant and might be removed. A fuller experimental protocol will be discussed with the skippers involved over the summer months. We will investigate several possible modifications to next season's trials including:

1) A plastic grid option
2) Different escape hole cover net types (smaller mesh sizes and pvc strips)
3) Forward pointing or controlled camera (to monitor behaviour in front of the tunnel entrance)
4) A Scanmar-like device as a single source acoustic deterrent.

The results of this season's work will also be conveyed to French colleagues and industry during July. It is anticipated that future work will be done in greater collaboration with the French industry through a multi-national project called NECESSITY, funded by the European Commission.

A short explanatory video of this work is currently under production.